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Introduction of a gas chromatograph that utilizes state-of-the-art technology

Dr. Jan Suhr, MeterQ Solutions GmbH
Dr. Achim Zajc, MeterQ Solutions GmbH

1 INTRODUCTION

After establishing GCs for CV measurement in the natural gas business the requirements of the industry didn't change significantly. Consequently, the GCs themselves didn't change much. Many of today's Gas Chromatographs closely resemble their counterparts from 10 years ago in appearance, functionality, and internal components.

We will be showing technology and results of a GC, that has been developed completely from scratch, using the progress of the last 15 years in electronics, software, and micro-machining. Based on that a complete C_{6+} analysis can be done in 45 seconds with detection limits of 1 ppm per component. Flexible GC configuration allows for additional H_2S and O_2 limit control with the same unit that does the CV measurement [1], while the ex-proof enclosure is no bigger than a shoebox. Due to its compact size the PGC can be used in a classical installation, as transmitter directly mounted on the pipeline or as mobile device in a suitcase. All variants have been approved and are already in use for custody transfer in Germany.

Another topic that should be addressed, that has been around a long time, is (bypass-) emissions of natural gas PGCs. To get meaningful results off a GC, gas needs to travel fast from the sampling probe to the GC, which is usually achieved by venting gas to atmosphere near the GC. The amount of climate active methane vented, is more than 20 times the amount the GC itself uses. We can present a clean solution, that eliminates the bypass altogether while guaranteeing a fast GC response.

A final section revolves around Hydrogen and the potential of our PGC for Hydrogen Quality and purity measurement.

2 Introduction

Having started a small company near Frankfurt in central Germany, we asked ourselves, if we could build a PGC for the German regulated custody transfer market. There were a handful of systems available, all of which were/are based on well-established technology. Looking back at 30 years plus combined experience in the market, we felt, that a lot of aspects could be improved, if one was willing to explore new approaches.

What would we need to achieve our goal of developing a PGC for the German regulated custody transfer market? Obviously first, we would need to find the right hardware as we are not GC hardware, electronic, or software developers. Having a suitable hardware, we would start to develop the application. The main challenge of the whole project is to design the application, that needs to fullfill the following criteria at the same time:

- Continuous unattended operation
- ATEX/IECEx Zone 1 compliance
- Fiscal stability, accuracy, linearity and repeatability
- PTB approval (German national metrological institute)
- User-friendly interface
- Optimizing serviceability with minimal maintenance requirements

The practical work would then encompass a lot of testing in our own lab and field testing with in a second stage and of course the actual PTB approval, which is prerequisite to introiducing the any GC in the German custody transfer market.

Once all components are in place, the iterative product improvement process begins, involving repeated cycles of the described steps.

3 Hardware

While the right (GC-)hardware is key to the success of the whole project the application is the framework, which converts the hardware into an actual system that can be legally and safely used for custody transfer of natural gas. Apart from the GC itself the system typically also includes peripherals: sampling probe, sample lines, pressure reduction unit, gas supply unit, controller, switching cabinet, remote communication, ….

As for the GC hardware, we were very lucky to get into contact with a company called Qmicro early on, who set out, just like we did, to develop a new micro-GC from scratch. Qmicro was the perfect partner. They would provide the hardware and we would do the application. When we initiated the collaboration approximately 8 years ago, both our project and theirs were in the early stages, comprising a collection of ideas and initial prototypes.

Key components of the GC were meticulously designed and developed using modern technology and machining methods, including MEMS. Doing so resulted in highly integrated and optimized column modules called channels with minimum leakage and heat capacity for very high accuracy and sensitivity. The configuration we use and call MGC^{flex} consists of a cartridge containing 3 separate GC channels, which is mounted on a host that holds the electronics and the pressure controlling parts. Both parts are inside shoebox sized Ex-d enclosure.

Fig. 1 - MGC^{flex}

The MGC^{flex} (Figure 1) uses Helium on channel 1 and 2 for the lower and higher hydrocarbons respectively and Argon on channel 3 for He, H_2, O_2, N_2 separation in its 14-component configuration. The whole GC weighs around 15 kg. and has a power consumption below 75 W. Today the system is PTB approved for custody transfer (gas quality, CV and density) in Germany and other European countries.

The cartridge performs a full natural gas 14 component analysis in 45 s including n-Butane/neo-Pentane separation. At the same time the detection limit is below 5 ppm. There are no maintenance requirements other than on-demand bake-out of the system, which can be initiated by a simple command in the software MGC$^{\text{monitor}}$.

The MGC$^{\text{flex}}$ was the pioneering complete system to undergo successful field-testing and secure PTB approval.

4 A mobile GC

In the last few years the number of gas composition tracking and/or CV tracking system has steadily increased in the German gas grid. In order to verify the calculated gas composion these system have to be checked on a regular basis. This is done by gas composition analysis at randomly chosen locations within the grid. The composition will be measured for a few days and compared to the computed results of the tracking system.

Verification measurements are done, using mobile PGCs. These mobile PGCs are standard PGCs installed in a big trailers, that can be hauled around and setup where they are needed. The big disadvantage of such a solution is that the trailer is big and heavy and can't be moved to confined spaces. This can lead to problems because the verification measurements are not typically done in big accessible stations.

Fig. 2 - MGC$^{\text{mobile}}$

Building upon the compact and user-friendly design of the MGC$^{\text{flex}}$, developing a portable version, the MGC$^{\text{mobile}}$ (Figure 2), was a natural progression. The MGC$^{\text{mobile}}$ is designed to be a really portable device for verification measurements and as temporary replacement for a a (defect) regular unit. It received PTB approval, alongside the MGC$^{\text{flex}}$, so it can be used for custody transfer measurements. The MGC$^{\text{mobile}}$ consists of the GC mounted in a wheeled suitcase with an internal mount for a 2 L calibration gas cylinder, external carrier gas inlets and a small electronics box for the controller and power supply. The main unit is ATEX zone 1 approved like the MGC$^{\text{flex}}$. The whole system fits in the trunk of most regular cars and can be setup in tight spaces. Setup and commissioning of the complete system can be done in less than 3 hours.

Fig. 3 - MGC$^{\text{mobile}}$ and trailer

In case the GC needs to be operated outside a building ("in the field") without grid power, the MGC$^{\text{mobile}}$ can be built with an additional small trailer that acts as a sort of garage for the system. The MGC$^{\text{mobile}}$ is mounted on rails in the back of the trailer, which can hold carrier gas and calibration gas cylinders and an optional fuel cell for independent power supply. It can be operated in the trailer that will act as weather and access protection, gas, and power supply at the same time. If the trailer is not needed, the MGC[mobile] can be easily removed and used. The trailer itself is typically only half of the length and weight of a classical one.

5 Natural gas emission reduction

Another issue that was mostly ignored but got into focus more and more in the last few years is methane emission and its greenhouse potential. The latest numbers attribute methane a climate activity of 28 [2], which means a methane emission is as greenhouse active as 28 times the amount of CO_2 emission.

For a PGC there are two possible sources of methane emissions. The first is the exhaust gas of the GC itself which consists of a mixture of sample and carrier gas. This is typically in the range of 1-2 l/h and is unavoidable. The second source is the bypass, which is generally variable but typically operated at around 50 l/h for a typical GC installation.

What the bypass does, is increasing the sample gas flow from the sample probe to the GC. to get meaningful measurement results, the sample needs to travel fast from the probe to the GC. The time the sample takes from the probe to the GC (sampling delay) added to the cycle time of the (GC delay) results in the total delay of the analysis result. For instance, if the sample delay is 5 minutes and the GC cycle time is 3 minutes, the GC will report the sample composition 8 minutes after the initial sampling. That doesn't sound much but can be problematic as the flowcomuter does volume correction with live flow data and the delayed results of the GC.

A high bypass setting means a short sample delay and high methane emissions. A low bypass setting results in a long sample delay and low methane emissions. There is no simple solution, but several things can be done to help with this problem. To find the optimal setting, one needs to calculate the actual delay in to decide which bypass setting is a good compromise between delay and emissions. The sample delay should typically not be significantly longer than the cycle time [3].

If one looks at the details of the calculation, it is easy to understand, where big delays come from and how to improve the installation for a minimum delay/bypass. Without going into too much detail, here is what can be done:

Fig. 4 - MGC[direct]

- Avoid any dead volumes in the sampling system especially on the HP side
- Put the GC as close as possible to the sampling probe (reduce the overalls length of the sampling system)
- Put the HP reduction as close as possible to the sampling probe (reducing the length HP portion of the sampling system)

While these considerations apply to any PGC, options are limited in a classical installation. The MGC[direct] is our solution to this problem. The GC is mounted in a small box which sits directly on top of the sampling probe. While the MGC[direct] needs external carrier and calibration gas lines, the design ensures the shortest possible sampling system with an integrated HP reduction and a special sampling probe, to feed back excess methane into the pipeline. This allows the operation of the GC with minimal sample delay (< 1 min) without the use of a bypass.

Compared to a typical GC installation the MGC^{direct} reduces methane emissions by a factor of 20 – 25 which is a reduction by more than 95%.

6 Hydrogen

In the last few years, the debate over the use of hydrogen as an alternative storage and transport medium for energy has grown more and more prominent and more specific at the same time. Today it is clear that there will be a hydrogen infrastructure for transport and storage. Research projects have been started in many countries to answer the multitude of questions that arise in this respect.

One complex of questions revolves around hydrogen quality. Of course, pure hydrogen does not have a composition, but in the real world any production or transport method, will impose impurities into the hydrogen. What impurities will these be. What quality can be produced? What quality will be needed? How does transport affect the quality? These questions are addressed by Get-H_2 which is part of the German flagship research project TransHyDE [4].

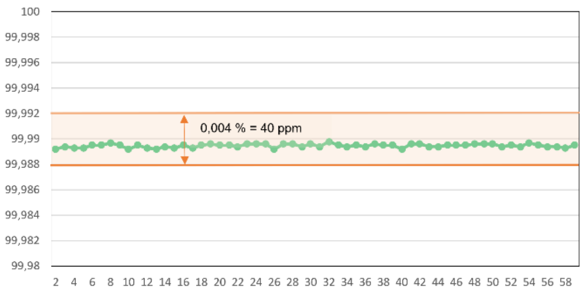

Fig. 5 - Repeatability of 60 hydrogen measurements

As project partner meterQ has developed the MGC^{hydrogen} to answer some of these questions. Its high sensitivity allows for trace measurements of impurities down to a concentration of 1 ppm, simultaneously measuring the hydrogen content within the range of 97 – 100 %. Figure 5 shows the repeatability of a hydrogen measurement. At 99,98 % hydrogen content it shows an impressive span that is well below 40 ppm (0,004 %).

The MGC^{hydrogen} has been lab tested and is now at PTB for a performance verification. By the beginning of 2024, it will be installed and utilized for assessing hydrogen quality in the experimental hydrogen pipeline in Lingen.

7 Conclusion

Over the past 8 years, our dedicated efforts have demonstrated the potential for significant progress in the Process Gas Chromatograph (PGC) technology for natural gas. This market has always been conservative and PGCs have been around for a long time. They can certainly be called a mature technology. This is typically not the context where big changes happen frequently.

We have managed to take a big step forward with our new MGC series PGCs. It might not be a revolution, but it is certainly received very well in the German market and is also being recognized outside of Germany, as well. We have shown that a good PGC should be based on good hardware, but that it is much more than hardware alone. Starting from scratch and not being afraid to think-out-of-the-box really makes the difference.

8 NOTATION

CV	Calorific Value
GC	Gas Chromatograph
HP	High Pressure
PGC	Process Gas Chromatoigraph
PTB	Pysikalisch Technische Bundesanstalt

7 REFERENCES

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